Towards coupling coastal ocean models to inland hydrology at NOAA National Ocean Service

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Content

- Coastal ocean modeling framework
- Unified Forecast System
- NOS’ Coastal Ocean Models and UFS
- Some of the on-going projects
- Future works
Coastal ocean modeling framework

- Inundation
- Navigation
- Water Quality
- Sediment Transport

Example Products
- Maps and Visualizations
- Ensembles, Probabilities
- Product Uncertainties
- Wave Conditions
NOS’ Long-Term Strategy

The long-term approach regarding NOS coastal modeling capability is to *move towards implementing full 3D coastal modeling linked to the inland hydrology models, on a national scale.*

We have identified that *direct coupling of the coastal circulation model to the inland hydrology model is the long-term approach for NOS’ national scale coastal circulation models.*

Boundary conditions from NOS’ operational models are always available to National Water Center or other NOAA partners to support their inland flood modeling efforts.
NUOPC Layer interoperability rules are implemented using a set of *generic components* that represent the major structural pieces needed to build coupled models.

**Unified Forecast System (UFS)**

**National Unified Operational Prediction Capability (NUOPC) Layer**

<table>
<thead>
<tr>
<th>NUOPC Generic Components</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Driver</strong></td>
<td>Harness that initializes components according to an <em>Initialization Phase Definition</em>, and drives their Run() methods according to a customizable run sequence.</td>
</tr>
<tr>
<td><strong>Connector</strong></td>
<td>Implements field matching based on standard metadata and executes simple transforms (e.g. grid remapping, redistribution). It can be plugged into a generic Driver component to connect Models and/or Mediators.</td>
</tr>
<tr>
<td><strong>Model</strong></td>
<td>Wraps model code so it is suitable to be plugged into a generic Driver component.</td>
</tr>
<tr>
<td><strong>Mediator</strong></td>
<td>Wraps custom coupling code (flux calculations, averaging, etc.) so it is suitable to be plugged into a generic Driver component.</td>
</tr>
</tbody>
</table>

_Theurich et al. 2016_
#### ESMF/NUOPC enabled models (Selected)

<table>
<thead>
<tr>
<th>CST</th>
<th>Coastal ocean</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATM</td>
<td>atmosphere</td>
<td>FV3 (Finite-Volume Cubed-Sphere Dynamical Core), GSM (Global Spectral Model), NMMB (Non-hydrostatic multiscale model on the B-grid), WRF</td>
</tr>
<tr>
<td>OCN</td>
<td>ocean</td>
<td>MOM5 and MOM6 (Modular Ocean Model)</td>
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<tr>
<td>WAV</td>
<td>wave</td>
<td>WWIII (WAVEWATCH III)</td>
</tr>
<tr>
<td>ICE</td>
<td>sea ice</td>
<td>CICE (Los Alamos Sea Ice Model), KISS (Keeping Ice's Simplicity)</td>
</tr>
<tr>
<td>HYD</td>
<td>hydrology</td>
<td>WRF-Hydro (Weather Research and Forecast Model Hydrology), NWM</td>
</tr>
<tr>
<td>LND</td>
<td>land</td>
<td>LIS (Land Information System)</td>
</tr>
</tbody>
</table>

- **Validating**
- **In development**
- **Plan to develop**
<table>
<thead>
<tr>
<th>Application</th>
<th>ATM</th>
<th>OCN</th>
<th>WAV</th>
<th>ICE</th>
<th>HYD</th>
<th>LND</th>
<th>AER</th>
<th>IPM</th>
<th>CST</th>
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<tbody>
<tr>
<td>COASTAL Act</td>
<td>HWRF</td>
<td></td>
<td>WWIII</td>
<td></td>
<td>NWM</td>
<td></td>
<td></td>
<td></td>
<td>ADCIRC</td>
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<tr>
<td>NWI-ROMS</td>
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<td>WWIII</td>
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<td>NWM</td>
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<td>ROMS</td>
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<tr>
<td>NWI-FVCOM</td>
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<td>NWM</td>
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<td>WRF</td>
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<td>ROMS</td>
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<tr>
<td>OTT-Alaska</td>
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<td>RTOFS</td>
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COASTAL Act application
NOAA’s Environmental Modeling System (NEMS)

NUOPC components
- Driver
- Model
- Connector

NOAA Technical Memorandum NOS CS 41
DEVELOPMENT OF A FLEXIBLE COUPLING INTERFACE FOR ADCIRC MODEL FOR COASTAL INUNDATION STUDIES

Moghimi et al, 2019;
Moghimi et al, in submission

WaveWatch III and ADCIRC sub-system validation
Boer, 1996 wave flume test case

Wave height
Set-up

Wave height
Set-up
HWRF+WW3 to ADCIRC for Sandy, 2012
HWRF+WW3+ADCIRC for Ike, 2008

Wave Height

Wind

Surge

Max surge

Moghimi et al, in submission
HWRF+WW3 to ADCIRC for Ike, 2008

IKE Fully coupled - Only tide

IKE Fully coupled - Stand Alone

Dynamical effects on maximum water level

Moghimi et al, in submission
HWRF+WW3 to ADCIRC for Ike, 2008

Trans A: maximum water level and wave height

Moghimi et al, in submission
Comparing ADCIRC and NWM (inland hydrology) coverage

NWM input is not included in the model results.

HSOFS mesh coverage
~1.8M nodes,
Hurricane Isabel

Hurricane Andrew

Hurricane Ike

Hurricane Sandy

ISA ATM&WAV2OCN - Only tide

AND ATM&WAV2OCN HWRF - Only tide

SAN 3DVar WAV - Only tide

10 km
Inland hydrology and coastal ocean models coupling

Discharges from NWM

Lateral fluxes from NWM
Exploring Creek-to-Ocean 3D modeling
SCHISM and NWM

In collaboration with:
Virginia Institute of Marine Science
SCHISM model domain

- Un-smoothed bathymetry
- USGS high-resolution DEM (NAVD88) (flat datum)
- Explicitly representing NWM segments in the horizontal mesh: 759K nodes and 1,478K elements
- Grid resolution: 2~7 km in the ocean; 50-200 m in the main channel of DB; down to ~20m in small streams
- Terrain following vertical mesh with varying number of layers (LSC$^2$)
- 3rd order transport scheme based on WENO
- Ocean boundary forced by HYCOM
- Hot start from HYCOM (with approximated salinity/temperature field inside the Delaware Bay)
- Atmospheric forcing from ECMWF (ERA)
- freshwater inflow inside Delaware Bay from NWM

- Simulation period: 2011-7-27 ~ 2011-9-10 (50 days)
- Time step: 150 seconds
- Baseline (3D baroclinic): 80x Real Time on 1440 cores of Pleiades (NASA)
- The 2D model runs approximately 57 times faster than the baseline and can be efficiently conducted using as few as 40 cores.

☐ Use a large domain for storm surge
☐ Resolve Gulf Stream to get baroclinic response right during storms
☐ Coupled with National Water Model (NWM) at 10 m above MSL
☐ Seamless creek-to-ocean capability
Coupling to NWM

- The intersection points between NWM Segments and the SCHISM land boundary are determined.
- NWM flows are directly imposed based on the streamflow of the intersecting segments.
- One-way coupling at the moment, from NWM to SCHISM

Ye et al, in press; Ocean Modelling
Mesh Generation for DE Bay

- The ocean model mesh overlaps with NWM’s coverage of streams
- NWM streams are explicitly represented in the SCHISM mesh
- The pluvial processes below the 10-m contour are directly handled by SCHISM.

![Diagram showing mesh generation for DE Bay](image)

10-m contour, MSL contour, channels

NWM Segments within the area of 0-10 m above MSL

NWM Segments
Baroclinic model setup

Terrain following vertical mesh with varying number of layers (LSC^2):

19 levels on average, 1 vertical layer if depth is shallower than 0.5m

Over 30% of the mesh cells are 2D and are dry most of the time

Ye et al, in press; Ocean Modelling
Waves contribution in the maximum elevation (Irene, 2011)

Zhang et al; Submitted; Ocean dynamics
Compound freshwater and coastal flooding effect (Irene, 2011)

(a) with streamflow inputs from NWM;
(b) without streamflow inputs;
(c) the difference between (a) and (b);

Zhang et al; Submitted; Ocean dynamics
~ 1 m increase in inundation level due to freshwater and coastal water compound flooding

Zhang et al; Submitted; Ocean dynamics

Compound freshwater and coastal flooding effect (Irene, 2011)
Future works

- Working with models developers and community to enable NOS’ operational models for absorbing inland hydrology variables (i.e. discharges and locally generated run-off)
- **ADCIRC**
  - Adaptive data driven mesh generation
  - Testing strategies for freshwater variables
  - Updating ADCIRC NUOPC/ESMF interface
- **ROMS**
  - Testing NUOPC/ESMF model interface in NOAA NEMS environment
  - Implementation of flexible freshwater source terms
  - Considering open-channel type bottom roughness for rivers
- **FVCOM**
  - Developing NUOPC/ESMF model interface in NOAA NEMS environment
  - Testing flexible freshwater source terms for seamless NWM and FVCOM coupling
NOAA Office of Coast Survey has been the nation’s nautical chart-maker since President Thomas Jefferson requested a hydrographical survey in 1807.

Questions!?
Hydraulic jump

Zhang et al; Submitted; Ocean dynamics